Free-Breathing Steady-State Free Precession 3D Coronary MRA: Comparison of Diaphragm and Cardiac Fat Navigator Gating Techniques

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INTRODUCTION

Current free-breathing coronary MRA (CMRA) employs diaphragm navigator (DNAV) gating to suppress respiratory motion (1,2), but its effectiveness can be suboptimal if the correlation between diaphragmatic and respiration-induced cardiac motions is poor (3). To overcome this limitation, the cardiac fat navigator (FNAV) was developed to provide a direct measurement of cardiac motion by using the epicardial fat signal for motion tracking. A preliminary study suggested that FNAV provides more effective motion suppression than DNAV for spoiled gradient echo (SPGR) 3D CMRA, but the statistical significance of the image quality improvement was not conclusive (4). Moreover, balanced SSFP imaging has recently replaced SPGR imaging as the state-of-the-art sequence for 3D CMRA (5). The objective of this study was to compare the performance of DNAV and FNAV in free-breathing SSFP 3D CMRA and to determine the statistical significance of the differences in image quality, SNR, CNR, and navigator efficiency between the two techniques.

MATERIALS AND METHODS

Fig.1 shows the implemented free-breathing CMRA sequence schematically. After a trigger delay (TD), spatial saturation (SPSAT) pulses were used to suppress the chest wall signal (including fat) for the subsequent FNAV. FNAV consisted of a 16-ms fat-selective RF followed by cranial-caudal k-space sampling to monitor cardiac motion. DNAV consisted of a 2D selective RF oriented in the cranial-caudal direction to monitor the motion of the right hemi-diaphragm. A fat saturation pulse (FATSAT) was used to suppress the epicardial fat, followed by a 6 Kaiser ramp-up magnetization preparation (6KR) to drive spins into steady state for subsequent SSFP data acquisition during the cardiac rest period.

Sixteen volunteers (11 men, 5 women, mean age of 32 ± 10 years) were imaged at 1.5T (GE Excite HDx) using an 8-channel cardiac phased-array coil. The typical imaging parameters were: TR/TE/FA/rBW = 4.0 ms/1.5 ms/60°/±62.5 kHz, resolution = 1.0x1.0x3.0 mm^3, 32 partial echoes per heartbeat. A custom gating program was implemented to collect navigator data, extract motion information, and control data acquisition in real time. The PAWS gating algorithm (6), which optimizes gating window selection and minimizes residual motion artifacts through view ordering, was used with a gating window of 5 mm for DNAV and 2.5 mm for FNAV (corresponding to a slope factor of 0.5 as reported in (4)). The DNAV and FNAV gated coronary sequences were performed in random order. Image quality difference was assessed by three experienced observers using randomized image pairs (five-point scale: markedly better, moderately better, similar, moderately worse, and markedly worse). Motion artifacts and coronary delineations were used as criteria in quality scoring. The scores were combined with differences resolved by majority. Blood SNR and blood-myocardium CNR were also calculated.

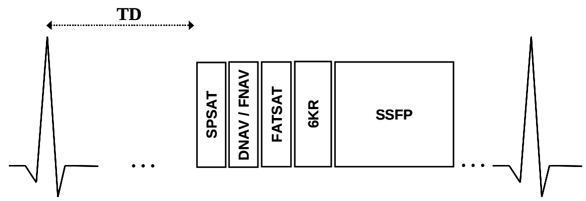

Fig.1. Schematics of the navigator gated SSFP 3D CMRA.

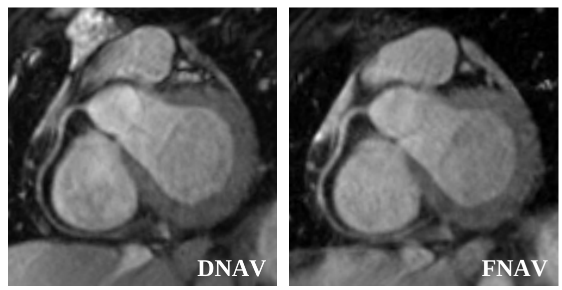

Fig.2. CMRA of similar quality obtained with DNAV and FNAV gating.

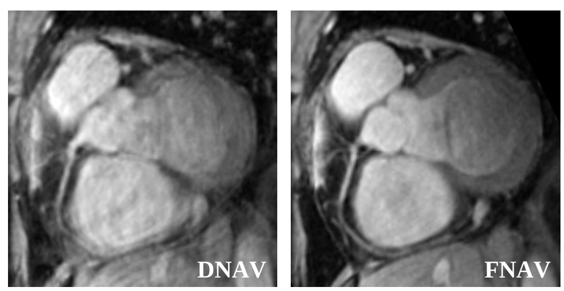

Fig.3. FNAV gating provided reduced motion artifacts and improved delineation of the RCA compared to DNAV gating.

	SNR	CNR	Efficiency (%)	Scan time (s)
DNAV	85 ± 17	48 ± 14	40 ± 12	340 ± 122
FNAV	87 ± 18	50 ± 14	52 ± 12	261 ± 77
P	0.5	0.2	0.002	0.01

Table 1. Comparison of DNAV and FNAV gated CMRA.

RESULTS

Compared to DNAV gating, FNAV gating provided markedly better image quality in 4 subjects, moderately better quality in 5 subjects, and similar quality in 7 subjects ($P<0.01$). Diagnostically interpretable CMRA was obtained in all subjects with FNAV gating (0% failure rate) and only 14/16 subjects with DNAV gating (12% failure rate). Fig.2 illustrates a case where DNAV and FNAV gating techniques produced similar image qualities of the RCA with negligible motion artifacts. Fig.3 shows FNAV more effectively suppressing motion than DNAV, leading to superior visualization of the RCA and better overall image quality. When DNAV gating failed, severe ghosting and blurring of the coronary arteries and the cardiac chambers were observed. While minor differences in SNR and CNR were not statistically significant (Table 1), FNAV gating provided a 30% improvement in average navigator efficiency compared to DNAV gating.

CONCLUSION Our preliminary results have demonstrated that FNAV gating provides more effective motion suppression and better image quality than DNAV gating for free-breathing SSFP 3D CMRA. The ability of FNAV to directly track cardiac motion can improve the sensitivity of current free-breathing CMRA and warrants further evaluation in a patient population.

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